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Documentation of WinDS Base Case Data

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Introduction

The **Win**d **D**eployment **S**ystems (WinDS) model is a computer model that optimizes the regional expansion of electric generation and transmission capacity in the continental United States over the next 50 years. WinDS competes many different generation types to design a "least-cost" electric power system under a number of technical, reliability, and environmental constraints. Detailed documentation of the WinDS model formulation is available at http://www.nrel.gov/analysis/winds/detailed.html.

This document summarizes the key data inputs to the Base Case of the WinDS model. The Base Case was developed simply as a point of departure for other analyses to be conducted with the WinDS model. It does not represent a forecast of the future, but rather is a consensus scenario whose inputs depend strongly on others' results and forecasts. For example, the WinDS Base Case derives many of its inputs from the EIA's

Annual Energy Outlook (EIA 2005) – in particular, its conventional technology cost and performance parameters, its current and future fossil fuel prices, and its electric-sector loads.

The sections that follow present the parameters and input values used for the WinDS Base Case.

1) Financials

WinDS optimizes the electric power system "build," based on the projected life-cycle costs, which include capital costs and cumulative discounted operating costs over a fixed evaluation period. The "overnight" capital costs are adjusted to reflect the actual total cost of construction, including tax effects, interest during construction, and financing mechanisms. **Table 1** provides a summary of the financial values used to produce the net capital and operating costs.

Table 1: Base Case Financial Assumptions

Name	Value	Notes & Source
Inflation Rate	3%	Based on recent historical inflation rates
Real Discount Rate	8.5%	Equivalent to weighted cost of capital. Based on EIA assumptions (U.S. DOE 2005b)
Debt/Equity Ratio	0	Consistent with the use of a weighted cost of capital for the real discount rate
Real interest rate	0	Consistent with the use of a weighted cost of capital for the real discount rate
Marginal Income Tax Rate	40%	Combined Federal/State Corporate Income Tax Rate
Evaluation Period	20 Years	Base Case Assumption
Depreciation Schedule		
Conventionals	15 Year	MACRS
Wind	5 Year	MACRS
Nominal Interest rate during construction	10%	Base Case Assumption
Dollar year	2004	All costs are expressed in year 2004 dollars

2) Power System Characteristics

2.1 WinDS Regions

There are four types of regions used in the WinDS model, illustrated in **Figure 1**. These include:

a) **Interconnect Regions** – There are three major interconnects in the United States: the Eastern interconnect, Western interconnect, and the ERCOT (Electric Reliability Council of Texas) interconnect. These are electrically isolated regions.
b) **National Electric Reliability Council (NERC) Subregions** – There are 13 NERC subregions used in WinDS. **Table 2** provides a listing of NERC region names and locations.
c) **Power Control Areas (PCAs) –** There are 136 PCAs used in WinDS.
d) **Wind Resource Regions –** There are 358 wind resource regions.

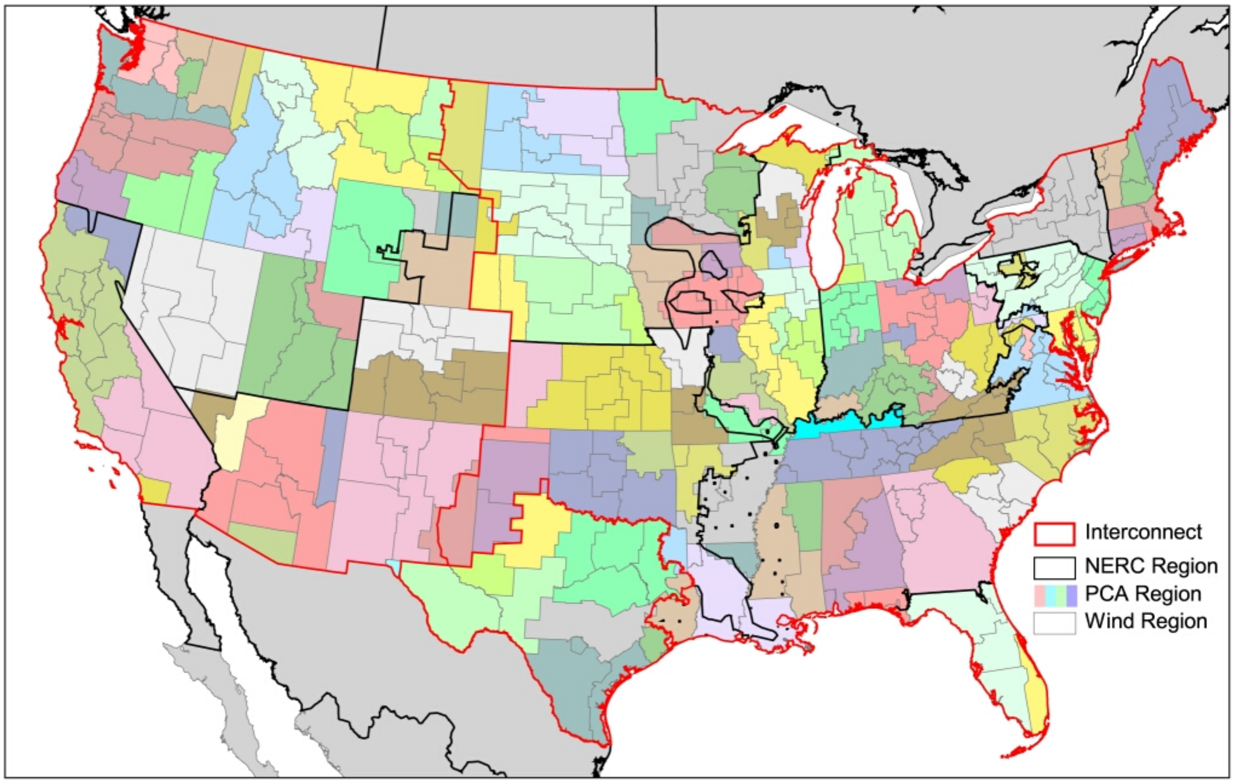

Figure 1: Regions Within WinDS

Interconnect regions, NERC regions, and PCAs are defined by various regulatory agencies – see **Table 2** for a definition of NERC regions.

Table 2: NERC Regions Used in WinDS

NERC Region/Subregion	Abbreviation	Region Name
1	ECAR	East Central Area Reliability Coordination Agreement
2	ERCOT	Electric Reliability Council of Texas
3	MAAC	Mid-Atlantic Area Council
4	MAIN	Mid-America Interconnected Network
5	MAPP	Mid-Continent Area Power Pool
6	NY	New York
7	NE	New England
8	FRCC	Florida Reliability Coordinating Council
9	SERC	Southeast Reliability Council
10	SPP	Southwest Power Pool
11	NWP	Northwest
12	RA	Rocky Mountain Area
13	CNV	California/Nevada

Note: NERC regions in WinDS are based on the pre-2006 regional definitions defined by http://www.eia.doe.gov/cneaf/electricity/ipp/html1/tb5p01.html. In January 2006, NERC regions were redefined (see http://www.nerc.com/regional/). However, the EIA will not incorporate these changes until publication of AEO 2007; therefore, WinDS will continue to use pre-2006 definitions until then.

Wind Resource Regions were created specifically for the WinDS model. The regions have been selected using the following rules and criteria:

a) Build up from counties (so that electric load can be determined for each wind supply/demand region based on county population).
b) Do not cross state boundaries (so that state-level policies can be modeled).
c) Conform to power-control areas as much as possible (to better capture the competition between wind and other generators).
d) Separate major windy areas from load centers (so that the distance from a wind resource to a load center can be well approximated).
e) Conform to NERC region/subregion boundaries (so that the results are appropriate for use by integrating models that use the NERC regions/subregions).

A detailed map with all wind regions and PCAs is provided in **Appendix A.**

The need for four levels of geographical resolution is based on several different components of the WinDS model. For example, electric demand is modeled at the NERC region level, while wind-generator performance is modeled at the wind-resource region level. The use of these various regions is discussed in further detail in the appropriate section in this document.

2.2 Electric System Loads

Loads are defined by region and by time. WinDS meets both the energy requirement and the power requirement for each of 136 Power Control Area (PCA) regions. Energy is met for each PCA in each of 16 time slices, and within each year modeled by WinDS. Time slices are defined in **Table 3.**

Table 3: WinDs Demand Time-Slice Definitions

Slice Name	Number of Hours Per Year	Season	Time Period
H1	**1152**	Summer	Weekends plus 11PM-6AM weekdays
H2	**462**	Summer	Weekdays 7AM-1PM
H3	**264**	Summer	Weekdays 2PM-5PM
H4	**330**	Summer	Weekdays 6PM-10PM
H5	**792**	Fall	Weekends plus 11PM-6AM weekdays
H6	**315**	Fall	Weekdays 7AM-1PM
H7	**180**	Fall	Weekdays 2PM-5PM
H8	**225**	Fall	Weekdays 6PM-10PM
H9	**1496**	Winter	Weekends plus 11PM-6AM weekdays
H10	**595**	Winter	Weekdays 7AM-1PM
H11	**340**	Winter	Weekdays 2PM-5PM
H12	**425**	Winter	Weekdays 6PM-10PM
H13	**1144**	Spring	Weekends plus 11PM-6AM weekdays
H14	**455**	Spring	Weekdays 7AM-1PM
H15	**260**	Spring	Weekdays 2PM-5PM
H16	**325**	Spring	Weekdays 6PM-10PM

The electric load in 2000 for each PCA and time slice is derived from an RDI/Platts database (http://www.platts.com/Analytic%20Solutions/BaseCase/). **Figure 2** is the WinDS load duration curve for the entire United States for the base year, illustrating the 16 load time slices. As a reference, the actual U.S. coincident load duration curve is illustrated as well (also derived from the Platts database). This aggregated data for the United States, which is shown in **Figure 2,** is not used directly in WinDS, as the energy requirement is met in each PCA. However, this curve does give a general idea of the WinDS energy requirement. It should be noted that the load-duration curve does not include the “super peak,” which occurs in most systems for a few hours per year. The peak requirements are discussed in **Section 2.3**.

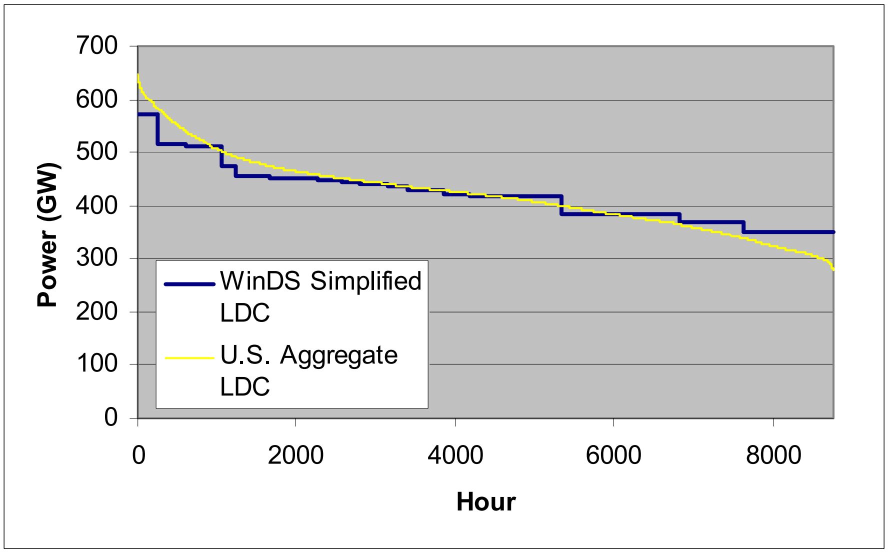

Figure 2: National Load Duration Curve for Base Year in WinDS

2.3 Growth Rate

Load growth is defined at the NERC Region level. It is assumed that the loads in all PCAs within each NERC region grow at the same rate to 2050. **Table 4** provides the 2000 load and annual growth rates for each NERC region.

Table 4: Base Load and Load Growth in the WinDS Base Case

NERC Region/Subregion	Abbreviation	2000 Load TWh/year	Annual Load Growth
1	ECAR	370	1.019
2	ERCOT	205	1.021
3	MAAC	197	1.016
4	MAIN	184	1.018
5	MAPP	110	1.017
6	NY	109	1.017
7	NE	96	1.017
8	FL	141	1.019
9	SERC	589	1.017
10	SPP	132	1.012
11	NWP	176	1.025
12	RA	97	1.026
13	CNV	202	1.021

Source: U.S. DOE. 2005b (Tables 60 through 72 "Total Net Energy For Load")

WinDS assumes that the growth rate in each time slice is constant; i.e. the load shape remains the same for all regions.

2.4 Capacity Requirements

In each power control area, WinDS requires that firm capacity is available to meet the demand in each time slice (see national example of time-slice demand in **Figure 2**). In addition, for every NERC region and/or interconnect region, WinDS requires sufficient capacity to meet the peak instantaneous demand throughout the course of the year,[1] plus a peak reserve margin. This reserve margin requirement may be met by any generator type – or by interruptible load – based on the relative economics.

While these capacity requirements are implemented regionally, we illustrate their national impact in **Table 5.**

Table 5: National Capacity Requirements in the WinDS Base Case

Capacity Requirement	Total (GW)		Annual Growth Rate
	2000	2050	%
Average load in the summer peak time slice	571	1,452	1.9
Annual peak instantaneous load	702	1,783	1.9
Peak capacity to meet reserve margin	875	2,016	1.7

The peak reserve margin for each region is provided in **Table 6**. Reserve margin is ramped from initial value in 2000 to the 2010 requirement, and maintained thereafter. It is assumed that energy growth and peak demand grow at the same rate, and the load shape stays constant from one period to the next.

Table 6: Peak Reserve Margin

NERC Region	Abbreviation	2010 Required Reserve Margin
1	ECAR	0.12
2	ERCOT	0.15
3	MAAC	0.15
4	MAIN	0.12
5	MAPP	0.12
6	NY	0.18
7	NE	0.15
8	FL	0.15
9	SERC	0.13
10	SPP	0.12
11	NWP	0.08
12	RA	0.14
13	CNV	0.13

Note: Reserve margin data from Energy Observer Issue No. 2, July 2004, PA Consulting Group

[1] This instantaneous annual peak load is higher than the load in each of the 16 time slices, because the load in each time slice is the average load over the hours included in that time slice.

3) Wind

3.1 Wind-Resource Definition

Wind power classes are defined as follows:

Table 7. Classes of Wind Power Density

Wind Power Class	Wind Power Density, W/m^2	Speed m/s (mph)
3	300-400	6.4-7.0
4	400-500	7.0-7.5
5	500-600	7.5-8.0
6	600-800	8.0-8.8
7	>800	>8.8

Note: Wind speed measured at 50 meters above ground level
Source: Elliott and M.N. Schwartz 1993

The wind power density and speed are not used explicitly in WinDS. The different classes of wind power are distinguished in WinDS through the resource levels, capacity factors, turbine costs, etc., all of which are discussed in the paragraphs below.

3.2 Resources

The wind-resource dataset for the WinDS model is based on a "supply curve" for onshore, shallow offshore, and deep offshore. Each is expressed in the following format for each of the 358 wind supply regions in WinDS:

Example of format

Wind Region	Class 3 Resource (MW)	Class 4 Resource (MW)	Class 5 Resource (MW)	Class 6 Resource (MW)	Class 7 Resource (MW))
1	926.5	286.4	82.3	41.5	18.8
2	214.9	69	43.7	43.7	16.7
3	467.1	248.3	127.7	120.3	66.9
4	3265.6	2100.9	501.1	86.8	6.1

Refer to Appendix A for the WinDS resource dataset for all 358 wind regions

This regional wind-resource dataset is generated by multiplying the total available area of a particular wind resource by an assumed wind-farm density of 5 MW/km^2 (NREL 2006). The amount of land available for each class is based on a dataset for each of the 358 wind regions for onshore, shallow offshore, and deep offshore. The resource data is derived from a variety of sources outlined in **Table 8.**

Table 8: Data Source for Wind Resource

State	Data Source*	State	Data Source*	State	Data Source*
Arizona	2003, N/TWS	Maine	2002, N/TWS	Ohio	2004, N/TWS
Alabama	1987, PNL	Maryland	2003, N/TWS	Oklahoma	1987, PNL
Arkansas	1987, PNL	Massachusetts	2002, N/TWS	Oregon	2002, N/TWS
California	2003, N/TWS	Michigan	2005, N/TWS	Pennsylvania	2003, N/TWS
Colorado	2003, N/TWS	Minnesota	1987, PNL	Rhode Island	2002, N/TWS
Connecticut	2002, N/TWS	Mississippi	1987, PNL	South Carolina	1987, PNL
Delaware	2003, N/TWS	Missouri	2004, N/TWS	South Dakota	2000 NREL
Florida	1987, PNL	Montana	2002, N/TWS	Tennessee	1987, PNL
Georgia	1987, PNL	Nebraska	2005, N/TWS	Texas	1987, PNL/2000 NREL
Idaho	2002, N/TWS	Nevada	2003, N/TWS	Utah	2003, N/TWS
Illinois	2001, NREL	New Hampshire	2002, N/TWS	Vermont	2002, N/TWS
Indiana	2004, N/TWS	New Jersey	2003, N/TWS	Virginia	2003, N/TWS
Iowa	1987, PNL	New Mexico	2003, N/TWS	Washington	2002, N/TWS
Kansas	1987, PNL	New York	1987, PNL	West Virginia	2003, N/TWS
Kentucky	1987, PNL	North Carolina	2003, N/TWS	Wisconsin	1987, PNL
Louisiana	1987, PNL	North Dakota	2000 NREL	Wyoming	2002, N/TWS

* Year validated (1987 to present);
Source = PNL, NREL, or N/TWS (NREL with AWS TrueWind – see Note 3)

Notes:

1) PNL data cells are each 1/4 degree of latitude by 1/3 degree of longitude. Each cell has a terrain exposure percent, ranging from 5% for ridge crest to 90% for plains, which defines the fraction of the area in each cell that is available for wind development. (PNL 1987)

2) NREL data was generated with the WRAMS model (NREL 2004), and does not account for surface roughness. Resolution is 1 km.

3) N/TWS data was generated by AWS TrueWind and validated by NREL. Resolution is 400 m for the northwest states (WA, OR, ID, MT, and WY) and 200 m everywhere else. These data consider surface roughness in their estimates. (http://www.awstruewind.com/inner/services/windmapping.htm).

The wind-resource availability in WinDS includes many land exclusions described in **Table 9**. These exclusions are based on NREL program assumptions.

Table 9: Wind-Resource Exclusion Database – Standard Version, January 2005

Criteria for Defining Available Windy Land (numbered in the order they are applied):	
Criteria	***Data/Comments*:**
1) Exclude areas of slope > 20%	Derived from elevation data used in the wind resource model.
2) 100% exclusion of National Park Service and Fish and Wildlife Service managed lands	USGS Federal and Indian Lands shapefile, Jan 2005
3) 100% exclusion of federal lands designated as park, wilderness, wilderness study area, national monument, national battlefield, recreation area, national conservation area, wildlife refuge, wildlife area, wild and scenic river or inventoried roadless area.	USGS Federal and Indian Lands shapefile, Jan 2005
4) 100% exclusion of state and private lands equivalent to criteria 2 and 3, where GIS data is available.	State/GAP land stewardship data management status 1, from Conservation Biology Institute Protected Lands database, 2004

5) 100% exclusion of airfields, urban, wetland and water areas.	USGS North America Land Use Land Cover (LULC), version 2.0, 1993; ESRI airports and airfields (2003)
6) 100% exclude 3 km surrounding criteria 2-5 (except water)	Merged datasets and buffer 3 km
7) Exclude resource areas that do not meet a density of 5 km^2 of class 3 or better resource within the surrounding 100 km^2 area.	Focalsum (a GIS function) applied to function of class 3+ areas (not applied to 1987 PNL resource data)
8) 50% exclusion of remaining USDA Forest Service (FS) lands (incl. National Grasslands)	USGS Federal and Indian Lands shapefile, Jan 2005
9) 50% exclusion of remaining Dept. of Defense lands	USGS Federal and Indian Lands shapefile, Jan 2005
10) 50% exclusion of state forest land, where GIS data is available	State/GAP land stewardship data management status 2, from Conservation Biology Institute Protected Lands database, 2004
11) 50% exclusion of non-ridgecrest forest. If an area is non-ridgecrest forest on FS land, it is just excluded at the 50% level one time.	Ridge-crest areas defined using a terrain definition script, overlaid with USGS LULC data screened for the forest categories.
Note - 50% exclusions are not cumulative.	

3.3 Basic Wind Cost and Performance

The following tables provide the Base Case inputs for projected cost and performance for land-based (onshore) and offshore (shallow and deep) wind turbines. The values were derived from data obtained from personal communication between the authors and Joseph Cohen at Princeton Energy Resources International (2003) for onshore turbines; and from Walter Musial at the National Wind Technology Center (2004) for offshore turbines. These datasets were manipulated to divide the cost/performance improvements into the factors that are due to industry learning-by-doing and those that are due to R&D. The improvements shown in **Table 10** represent that due only to R&D. The learning-by-doing improvements are calculated endogenously within WinDS, using an 8% learning rate (McDonald, 2001) based on both U.S. and world production estimates.

Table 10: Onshore Turbines (Values Constant after 2020)

Resource Class	Install Year	Capacity Factor	Capital cost ($/kW)*	Fixed O&M ($/kW-yr)	Variable O&M ($/MWh)
3	2000	0.2	942.60	7.54	4.71
3	2005	0.25	929.24	7.54	3.77
3	2010	0.275	922.57	7.54	3.71
3	2020	0.3	915.89	7.54	3.64
4	2000	0.251	942.60	7.54	4.71
4	2005	0.2885	915.89	7.54	3.77
4	2010	0.349	914.32	7.54	3.71
4	2020	0.361	898.61	7.54	3.64
5	2000	0.3225	942.60	7.54	4.71
5	2005	0.3535	897.82	7.54	3.77
5	2010	0.397	897.04	7.54	3.71
5	2020	0.4135	881.33	7.54	3.64

6	2000	0.394	942.60	7.54	4.71
6	2005	0.4185	879.76	7.54	3.77
6	2010	0.445	879.76	7.54	3.71
6	2020	0.466	864.05	7.54	3.64
7	2000	0.414	942.60	7.54	4.71
7	2005	0.4385	879.76	7.54	3.77
7	2010	0.465	879.76	7.54	3.71
7	2020	0.486	864.05	7.54	3.64

* Overnight capital cost

Table 11: Shallow Offshore Turbines (Values Constant after 2025)

Resource Class	Install Year	Capacity Factor	Capital cost ($/kW)	Fixed O&M ($/kW-yr)	Variable O&M ($/MWh)
3	2000	0.33	1194.00	10.00	15.00
3	2005	0.33	1194.00	10.00	15.00
3	2010	0.345	1143.83	10.00	14.13
3	2020	0.35	1073.67	10.00	13.07
3	2025	0.35	1064.33	10.00	12.77
4	2000	0.33	1194.00	10.00	15.00
4	2005	0.33	1194.00	10.00	15.00
4	2010	0.345	1143.83	10.00	14.13
4	2020	0.35	1073.67	10.00	13.07
4	2025	0.35	1064.33	10.00	12.77
5	2000	0.37	1194.00	10.00	15.00
5	2005	0.37	1194.00	10.00	15.00
5	2010	0.365	1143.83	10.00	14.13
5	2020	0.395	1073.67	10.00	13.07
5	2025	0.395	1064.33	10.00	12.77
6	2000	0.42	1194.00	10.00	15.00
6	2005	0.42	1194.00	10.00	15.00
6	2010	0.4375	1143.83	10.00	14.13
6	2020	0.445	1073.67	10.00	13.07
6	2025	0.445	1064.33	10.00	12.77
7	2000	0.44	1194.00	10.00	15.00
7	2005	0.44	1194.00	10.00	15.00
7	2010	0.4575	1143.83	10.00	14.13
7	2020	0.465	1073.67	10.00	13.07
7	2025	0.465	1064.33	10.00	12.77

Table 12: Deep Offshore (Cost and Performance Constant after 2025)

Resource Class	Install Year	Capacity Factor	Capital cost ($/kW)	Fixed O&M ($/kW-yr)	Variable O&M ($/MWh)
3	2000	0.33	2004.00	10.00	18.00
3	2005	0.33	2004.00	10.00	18.00
3	2010	0.345	1887.50	10.00	16.57
3	2020	0.35	1735.67	10.00	15.40
3	2025	0.35	1696.67	10.00	15.30

4	2000	0.33	2004.00	10.00	18.00
4	2005	0.33	2004.00	10.00	18.00
4	2010	0.345	1887.50	10.00	16.57
4	2020	0.35	1735.67	10.00	15.40
4	2025	0.35	1696.67	10.00	15.30
5	2000	0.37	2004.00	10.00	18.00
5	2005	0.37	2004.00	10.00	18.00
5	2010	0.365	1887.50	10.00	16.57
5	2020	0.395	1735.67	10.00	15.40
5	2025	0.395	1696.67	10.00	15.30
6	2000	0.42	2004.00	10.00	18.00
6	2005	0.42	2004.00	10.00	18.00
6	2010	0.4375	1887.50	10.00	16.57
6	2020	0.445	1735.67	10.00	15.40
6	2025	0.445	1696.67	10.00	15.30
7	2000	0.44	2004.00	10.00	18.00
7	2005	0.44	2004.00	10.00	18.00
7	2010	0.4575	1887.50	10.00	16.57
7	2020	0.465	1735.67	10.00	15.40
7	2025	0.465	1696.67	10.00	15.30

4) Conventional Generation

4.1 Generator Types

Available generator types that may be built are based on the most likely types as determined by the DOE Energy Information Administration (EIA) – U.S. DOE 2005c.

Table 13: Conventional (Non-Wind) Generation Types Considered by WinDS

Generator Type	Existing Capacity?	May Be Built New In WinDS?
Conventional pulverized coal steam plant (No SO2 Scrubber)	Y	No – Scrubbers may be added to meet SO2 constraints. Existing plants may also switch to low-sulfur coal
Conventional pulverized coal steam plants (With SO2 Scrubber)	Y	No
Advanced supercritical coal steam plant (With SO2 and NOx controls)	Y	Y
Integrated Coal Gasification Combined Cycle (IGCC)	Y	Y – sequestration may be added
Oil/Gas Steam Turbine (OGS)	Y	N – Assumes CT or CCGT will be built instead
Combined Cycle Gas Turbine	Y	Y – sequestration may be added
Gas Combustion Turbine	Y	Y
Fuel Cell	None	Not in Base Case – Generic Fuel Cell with H2 fuel is an optional technology
Nuclear	Y	Y

Conventional Hydropower - Hydraulic Turbine	Y	No – small hydro to be added
Municipal Solid Waste / Landfill Gas	Y	N – to be added
Biomass (as thermal steam generation)	Y	N – to be added in the form of co-firing, thermal steam, and/or gasification
Geothermal	Y	N – to be added
Concentrating solar power with storage	Y	Y

4.2 Cost and Basic Performance (Capital Cost, Fixed O&M, Variable O&M, Heat Rate)

Values for capital cost, heat rate (efficiency), fixed O&M, and variable O&M for conventional technologies are provided in **Table 14** for the Base Case. As shown in Table 14, real operating costs for existing steam plants are assumed to escalate at 2% per year, reflecting plant aging.

Table 14: Basic Cost and Performance Characteristics for Conventional Generation

Type	Install Date	Capital Cost $/kW*	Fixed O&M $/MW-yr	Var O&M $/MWh	Heat rate MMBTU/MWh
Gas-CT	2000	504	8,415	3.16	10.82
	2005	407	10,315	3.07	10.03
	2010	386	10,315	3.07	9.50
	2020	358	10,315	3.07	9.50
	2030	351	10,315	3.07	9.50
	2040	351	10,315	3.07	9.50
	2050	351	10,315	3.07	9.50
Gas-CC	2000	626	10,527	2.10	7.20
	2005	584	11,021	1.85	6.97
	2010	568	11,021	1.85	6.57
	2020	537	11,021	1.85	6.57
	2030	527	11,021	1.85	6.57
	2040	527	11,021	1.85	6.57
	2050	527	11,021	1.85	6.57
Existing Coal	2000	N/A	23,410	3.40	10
(Scrubbed)	2005	N/A	25,847	3.75	10
(see note # 6)	2010	204	28,537	4.14	10
	2020	204	34,786	5.05	10
	2030	204	42,404	6.16	10
	2040	204	51,690	7.51	10
	2050	204	63,010	9.15	10
Existing Coal	2000	N/A	27,156	3.94	10
(Unscrubbed)	2005	N/A	29,982	4.35	10
	2010	N/A	33,103	4.81	10
	2020	N/A	40,352	5.86	10
	2030	N/A	49,189	7.14	10
	2040	N/A	59,961	8.71	10
	2050	N/A	73,092	10.62	10

Coal-new	2000	1,249	25,091	4.18	8.84
	2005	1,249	25,091	4.18	8.84
	2010	1,232	25,091	4.18	8.67
	2020	1,193	25,091	4.18	8.6
	2030	1,176	25,091	4.18	8.6
	2040	1,176	25,091	4.18	8.6
	2050	1,176	25,091	4.18	8.6
Coal-IGCC	2000	1,444	25,091	2.58	8.31
	2005	1,444	25,091	2.58	8.31
	2010	1,406	25,091	2.58	7.52
	2020	1,305	25,091	2.58	7.2
	2030	1,182	25,091	2.58	7.2
	2040	1,182	25,091	2.58	7.2
	2050	1,182	25,091	2.58	7.2
Oil/gas/steam	2000	N/A	25,256	3.16	9
	2005	N/A	27,884	3.49	9.23
	2010	N/A	30,786	3.85	9.46
	2020	N/A	37,528	4.70	9.94
	2030	N/A	45,747	5.73	10.45
	2040	N/A	55,765	6.98	10.99
	2050	N/A	67,978	8.51	11.55
Nuclear	2000	2016	61,862	0.45	10.4
	2005	2016	61,862	0.45	10.4
	2010	1958	61,862	0.45	10.4
	2020	1862	61,862	0.45	10.4
	2030	1814	61,862	0.45	10.4
	2040	1814	61,862	0.45	10.4
	2050	1814	61,862	0.45	10.4

Source: U.S. DOE. 2005c.
Fossil capital costs: Table 48 (Reference Case)
Fossil heat Rates: Table 48 (Reference Case)
Nuclear capital cost: Table 49 (Reference Case)
Fixed and Variable O&M Table 38

Notes:
1) Capital costs are “overnight” costs not including interest during construction
2) The current AEO projects costs every 5 years to 2025. Values in WinDS are interpolated linearly to derive the even year values. For new plants, values beyond 2025 are assumed to be constant.
3) Cost values and heat rates for the Gas-CT and Gas-CC are based on the average of the “conventional” and “advanced” cases in the AEO.
4) New nuclear may not be constructed before 2010.
5) Old coal and oil/gas/steam may not be constructed in WinDS.
6) This value represents the cost of converting unscrubbed to scrubbed coal.
7) O&M = operation and maintenance. O&M costs do not include fuel.
8) Heat rate is net heat rate (including internal plant loads).
9) Values are interpolated for intermediate years in WinDS.

4.3 Capital Cost Adjustment Factors

There are several adjustments that are applied to the capital cost including financing, interest during construction, learning, and rapid growth.

In the Base Case, financing is not treated explicitly. It is assumed to be captured by the real discount rate of 8.5%, which is a weighted cost of capital.

Inasmuch as the capital costs of conventional technologies are taken from the EIA's Annual Energy Outlook report (and have, therefore, already been adjusted for learning), no additional learning is assumed for these technologies in the Base Case. As pointed out above, expected improvements in the cost and performance of future wind turbines have been separated into those that are due to learning and those that are due to R&D-driven improvements. The R&D-driven improvements for wind in the Base Case were reported in **Tables 10-12.**

In the Base Case, WinDS does assume that the price paid per unit of wind capacity can increase above the capital costs of **Tables 8-10,** if the demand for new wind capacity significantly exceeds that supplied in earlier years. In particular, if the new wind installations are more than 20% greater than those of the preceding year, there is a 1% increase in capital cost for each 1% growth above 20% per year (U.S. DOE 2004, p88). Interest during construction can also increase the effective capital cost for each technology. **Table 15** indicates the construction time and schedule for each conventional technology.

Table 15: Capital Cost Adjustment Factors

	Construction Time	Schedule
Hydro	NA	NA
Gas-CT	3	A
Gas-Combined Cycle (CC)	3	C
Coal-old-1 (Scrubbed)	3 (add scrubber to existing)	A
Coal-old-2 (Uncrubbed)	NA	NA
Coal-new	4	D
Coal-IGCC	4	D
Oil/gas/steam (o-g-s)	NA	NA
Nuclear	6	B
Geothermal	NA	NA
Biopower	NA	NA
Concentrating Solar (CSP)	3	C
Landfill Gas (lfill-gas)	NA	NA

Notes:
1) Construction time source: U.S. DOE. 2005a. Table 38.
2) Schedule refers to the fraction of capital cost that must be committed each year during construction. This is used to calculate interest, and the total capital cost required to build each plant. Assumed schedules are in **Table 16**.

Table 16: Generator Construction Schedules

	Fraction of Cost in Each Year					
Schedule	1	2	3	4	5	6
A	80%	10%	10%			
B	10%	20%	20%	20%	20%	10%
C	50%	40%	10%			
D	40%	30%	20%	10%		

4.4 Outage Rates (Forced Outage and Planned Outage)

WinDS considers the outage rate when determining the net capacity available for energy described in **Section 2**, and in determining the capacity value of each technology. Planned outages are assumed to occur in all seasons except the summer. **Table 17** provides the outage rate for each conventional technology.

Table 17: Conventional Generator Outage Rates

Generator Type	Forced Outage Rate (%)	Planned Outage Rate (%)
Hydro	2.0	5.0
Gas-CT	10.7	6.4
Gas-Combined Cycle (CC)	5.0	7.0
Existing Coal (Scrubbed)	7.9	9.8
Existing Coal (Unscrubbed)	7.9	9.8
Coal-new	7.9	9.8
Coal-IGCC	7.9	9.8
Oil/gas/steam (o-g-s)	7.9	9.8
Nuclear	5.0	5.0

Source: National Electric Reliability Council's (NERC) Generating Availability Data System (GADS). http://www.nerc.com/~gads/ Planned outage rate based on SOF (scheduled outage hours divided by total hours). Forced outage rate based on EFORd (Equivalent Forced Outage Rate demand). Derived from a data run from Mike Curley of NERC (3/12/03).

4.5 Emission Rates

Emission rates are estimated for SO_2, NOx, Mercury (Hg), and CO_2. **Table 18** provides the input emission rates (lbs/MMBTU of input fuel) for plants that use combustible fuel. Output emission rates (lb/MWh) may be calculated by multiplying input emission rate by heat rate.

Table 18: Input Emissions Rates (lbs/MMBTU fuel input)

	SO2	NOx	Mercury (Hg)	CO2
Hydro	0	0	0	0
Gas-CT	0.0034	0.08	0	122.1
Gas-Combined Cycle (CC)	0.0034	0.02	0	122.1
Existing Coal (Scrubbed)	0.26	0.448	0.0000046	207.3
Existing Coal (Uncrubbed)	1.7	0.448	0.0000046	207.3
Coal-new	0.09	0.02	0.0000046	207.3
Coal-IGCC	0.04	0.02	0.0000046	122.1
Oil/gas/steam (o-g-s)	0	0.1	0	122.1
Nuclear	0	0	0	0
Biopower	0	0	0	0
Concentrating Solar (CSP)	0.0065	0.02	0	30.5
Landfill Gas (lfill-gas)	0.045	0	0	0

Sources and Notes:
1) SO_2: SO_2 emissions result from the oxidization of sulfur contained in the fuel. Natural gas rate source: U.S. EPA. 1996, (AP-42 Section 3.1 Stationary Gas Turbines). SO_2 input emissions rate for coal is based on the fuel content of the fuel, and the use of post-combustion controls. The "base" emissions rate for existing and new conventional coal plants is based on a national average sulfur content of 0.9 lbs/MMBTU (1.8 lb SO_2/mmBTU). WinDS assumes the national average for "low sulfur" coal is 0.5 lbs SO_2/MMBTU. Values based on national averages from AEO Assumptions (U.S. DOE 2005c) Table 73. Scrubber removal efficiency is assumed to be 85% for retrofits, 95% for new plants (U.S. EPA. 1996 AP-42 Section 1.1.4 Controls).

2) NOx: NOx emissions result from the oxidization of Nitrogen in the air. It is not a result of the type of fuel burned, but the combustion characteristics of the generator. NOx emissions can be reduced through a large variety of combustion controls, or post combustion controls. NOx emissions are not restricted in the WinDS Base Case (see section on federal emissions standards). The emissions rates in Table 18 are national averages, Source: U.S. EPA. 2005 (EGrid 2000 National averages.)

3) Mercury. Mercury is a trace constituent of coal. Mercury emissions are unrestricted in the WinDS Base Case (see section on federal emissions standards).Emissions rates in Table 15 are averages and do not consider control technologies. Source: U.S. EPA. 2005 (EGrid 2000 National averages.)

4) CO_2: CO_2 emissions result from the oxidization of carbon in the fuel and emissions rate is based solely on fuel type, and therefore constant for all plants burning the same fuel type. All emissions are point-source emissions from the plant only (not "life-cycle" emissions). Natural gas emissions rates are from U.S. EPA 1996, (AP-42 Section 3.1 Stationary Gas Turbines). CO_2 content for coal is based on the national average from AEO Assumptions (U.S. DOE 2005c) Table 73. Biofuels are assumed to be carbon neutral. Landfill gas is assumed to have zero carbon emissions, since the gas would be flared otherwise. CSP plants burn a small amount of natural gas, resulting in CO_2 emissions. CO_2 emissions are not constrained in the WinDS Base Case.

4.6 Fuel Prices

Fuel prices for natural gas and coal are derived from projections from the AEO 2005 (U.S. DOE. 2005b - Energy Prices by Sector and Source). These tables provide the prices in each census region, which are then assigned to a NERC subregion used in WinDS. Prices in the AEO are projected to 2025. Beyond 2025, WinDS increases fuel prices at the same national annual average rate as projected by the AEO between 2015 and 2025.

Figure 3 illustrates the projected fossil fuel prices in constant 2004$. The prices are projected out to 2070, because WinDS attempts to design a cost-optimal system over an evaluation horizon of 20 years. Values to the right of the vertical line in Figure 3 (at 2025) are extrapolation of EIA fuel price projections. (Averages shown on graph do not reflect the "real" average – which would be weighted by sales – but are the average weighted by region.)

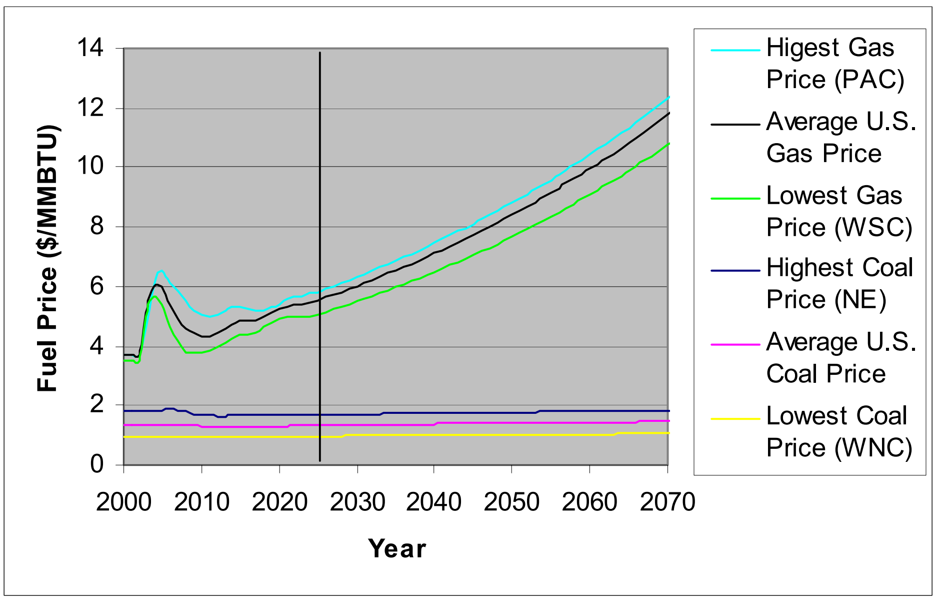

Figure 3: Projected Coal and Natural Gas Prices in WinDS to 2070

Uranium fuel price in WinDS is constant at $0.4/MMBTU (U.S. DOE. 2003, pg 68).

5) Transmission

WinDS assumes that some fraction of the existing transmission capacity may be used to deliver wind energy. WinDS may also build new transmission capacity dedicated to carrying wind energy.

Existing transmission capacity is estimated using a database of existing lines (length and voltage) from RDI/Platts (http://www.platts.com/Analytic%20Solutions/BaseCase/). This database is translated into a MW capacity, as a function of kV rating and length. (Weiss, Larry and S. Spiewak, 1998)

In the Base Case, it is assumed that only 20% of the capacity of an existing transmission line can be made available for new wind generation. This value is based partly on existing reserve margins, and also the possibility of upgrades to existing transmission systems – reconductoring, voltage upgrades, and the deployment of flexible AC transmission systems (FACTS).

WinDS uses a transmission loss rate of 0.236 kW per MW-mile. This value is based on the loss estimates for a typical transmission circuit (Weiss, Larry and S. Spiewak, 1998). The assumed "typical" line is a 200-mile, 230 kV line rated at 170 MVA (line characteristics derived from Electric Power Research Institute, 1983).

New transmission-line capacity may be constructed for wind at a cost of $1,000/MW-Mile. This value is based roughly on the middle range of estimates by the EIA (DOE 2002)

6) Federal and State Energy Policy

6.1 Federal Emission Standards

CO_2: WinDS has the ability to add a national cap on CO_2 emissions from electricity, or a CO_2 emission charge (tax). Neither a carbon cap nor charge is implemented in the Base Case.

SO_2: Emissions of SO_2 are capped at the national level. WinDS uses a cap that corresponds roughly to the 2005 Clean Air Interstate Rule (CAIR), replacing the previous limits established by the 1990 Clean Air Act Amendments. The CAIR rule divides the United States into two regions. WinDS uses the EPA's estimate of the effective national cap on SO_2 resulting from the CAIR rule.

Table 19 provides the SO_2 cap used in WinDS.

Table 19: National SO_2 Emission Limit Schedule in WinDS

Year	2003	2010	2015	2020	2030
National SO_2 Emissions (Million Tons)	10.6	6.1	5.0	4.3	3.5

Source: http://www.epa.gov/cair/charts_files/cair_emissions_costs.pdf

NOx: NOx emissions are currently unconstrained in WinDS. The NOx cap, based on the CAIR, may be added; however, the net effect on the overall competitiveness of coal is expected to be relatively small. (U.S DOE 2003b)

HG: Mercury emissions are currently unconstrained in WinDS. As of February 2006, the Clean Air Mercury Rule is a cap-and-trade regulation, expected to be met largely via the requirements of the CAIR rule. Control technologies for SO_2 and NOx that are required for CAIR are expected to capture enough mercury to largely meet the cap goals. As a result, the incremental cost of Hg regulations is very low (U.S. DOE 2003b), and not modeled in WinDS.

6.2 Federal Energy Incentives

There are several classes of incentives applied at the federal level. These incentives generally have the effect of reducing the cost of providing energy from an incentivized source. A production tax credit (PTC) provides an offset to the tax liability of companies, based on the production of energy from an incentivized source. An investment tax credit provides an offset to tax liability, based on investment in an incentivized source.

Table 20: Federal Renewable Energy Incentives

Name	Value	Notes and Source
Renewable Energy PTC	$19/MWh	Applies to wind. No limit to the aggregated amount of incentive. Value is adjusted for inflation. Expires end of 2007
Renewable Energy ITC	Solar CSP: 10%	

Source: U.S. Congress 2005

6.3 State Energy Incentives

Several states also have production and investment incentives for renewable energy sources. The values used in WinDS are listed in **Table 21**.

Table 21: State Renewable Energy Incentives

State	PTC $/MWh	ITC	Assumed State Corporate Tax Rate
IA		5.00%	10.0%
ID		5.00%	7.60
MN		6.50%	9.8%
NJ		6.00%	9.0%
NM	10		7.0%
OK	2.5		6.0%
UT		4.75%	5.0%
WY		4.00%	9.0%

Investment and production tax credit data from IREC 2006
Tax rates from: http://www.taxadmin.org/fta/rate/corp_inc.html

6.4 Federal Renewable Portfolio Standard

A renewable portfolio standard (RPS) requires that a certain fraction of a region's energy be derived from renewable energy. While there is no federal RPS in place (as of February 2006) or in the WinDS Base Case, WinDS can accommodate a national RPS, with input values for fraction of energy to be provided by renewables, RPS start year, duration, and shortfall penalty.

6.5 State Renewable Portfolio Standards

There are several states that currently have RPS policies. States may have capacity mandates as an alternative or supplement to an RPS. A capacity mandate requires a utility to install a certain fixed capacity of renewable energy generation.

Table 22: State RPS Requirements

State	RPS Start Year[2]	RPS Full Imple-mentation[3]	Penalty in $/MWh	WinDS Assumed RPS Fraction[4]	Legislated RPS Fraction (%)	Load Fraction[5]
AZ	2001	2025	50	0.0079	1.1	1
CA	2003	2017	5	0.034	20	0.63
CO	2007	2015	50	0.044	10	0.69
CT	2004	2010	55	0.013	10	0.94
DE	2007	2019	25	0.056	10	0.75
IL	2004	2013	10	0.062	15	0.92
MA	2003	2009	50	0.026	4	0.85
MD	2006	2019	20	0.045	7.5	0.8
MN	2002	2015	10	0.072	1,125 MW	1
MT	2008	2015	10	0.075	15	0.9
NJ	2005	2008	50	0.029	6.5	1
NM	2006	2011	10	0.026	10	0.53
NV	2003	2015	10	0.133	20	0.89
NY	2006	2013	5	0.035	25	0.84
OK	2005	2016	50	0.05	See Note 6	1
OR	2002	2020	5	0.078	See Note 6	1
PA	2007	2020	45	0.014	8	0.98
RI	2007	2019	55	0.069	15	0.99
TX	2003	2015	50	0.01	5,880 MW	1
VT	2005	2012	10	0.05	See Note 6	1
WI	2001	2011	10	0.006	2.2	0.75

Notes:
1) RPS data as of 8/16/05. Source: IREC 2006
2) RPS Start Year is the “beginning” of the RPS program. The RPS is ramped linearly to the full implementation year.
3) RPS Full Implementation is the year that the full RPS fraction must be met. WinDS assumes the fraction met is ramped up linearly between the start year and the full implementation year.
4) WinDS Assumed RPS Fraction is the fraction of state demand that must be met by wind by the full implementation year. This value is based on the total state RPS requirement and adjusted to estimate the fraction actually provided by wind since WinDS does not currently include other renewables such as biomass cofiring, certain hydro projects, etc.
5) Load fraction is the fraction of the total state load that must meet the RPS. In certain locations, municipal or cooperative power systems may be exempt from the RPS.
6) Several states have special funds set aside to promote renewables. The net increase in wind due to these funds was estimated and applied as an effective RPS.

7) Future Work

We continue to update and improve the data in the WinDS Base Case as it becomes available. For example, we will be updating the electric loads, fuel prices, and conventional technology costs and performance once the U.S. DOE Energy Information Administration releases the full dataset associated with the *Annual Energy Outlook 2006.*

8) References

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Note on EIA and EPA references: Many of the assumptions regarding conventional generation and fuel prices are from the Energy Information Administration's National Energy Modeling System (NEMS). This information is published in the Annual Energy Outlook (AEO), which consists of three documents: the main AEO (which focuses on results), the supplemental tables (which provide additional details on results at the regional level), and the assumptions (which provides input details). Several sources for emissions data are available from the U.S. EPA. These include the AP-42 series of documents, which provide detailed emissions estimates for different combustion technologies and emissions controls. The eGRID database provides estimates for actual emission rates from existing plants, based on measured fuel use and Continuous Emissions Monitoring System (CEMS) data measurement.

Appendix A: Wind Resource Dataset

Refer to Section 3 for details of dataset origins.

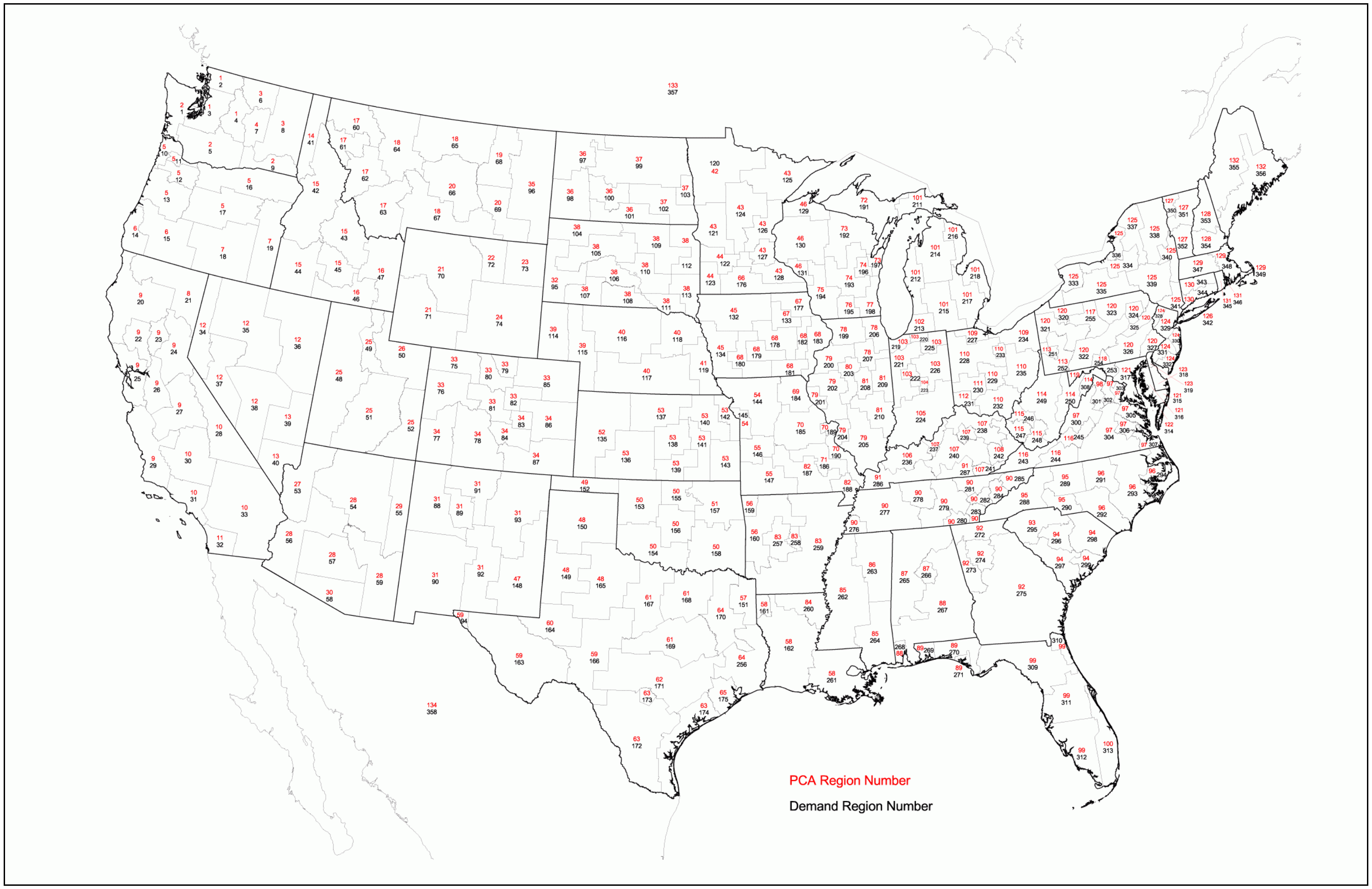

Figure A.1: Wind Region and PCAs in WinDS Base Case

Table A1: Wind Resource by WinDS Region

Wind	On Shore Resource (MW)					Shallow Offshore Resource (MW)					Deep Offshore Resource (MW)				
Region	Class 3	Class 4	Class 5	Class 6	Class 7	Class 3	Class 4	Class 5	Class 6	Class 7	Class 3	Class 4	Class 5	Class 6	Class 7
1	927	286	82	42	19	0	155	0	0	0	802	1408	18686	51017	0
2	215	69	44	44	17	4	7	0	0	0	110	112	0	0	0
3	467	248	128	120	67	3	31	0	0	0	0	142	0	0	0
4	3266	2101	501	87	6	0	0	0	0	0	0	0	0	0	0
5	10416	2550	542	267	61	0	0	0	0	0	0	0	0	0	0
6	65	18	2	0	0	0	0	0	0	0	0	0	0	0	0
7	1512	186	30	4	0	0	0	0	0	0	0	0	0	0	0
8	614	131	59	26	2	0	0	0	0	0	0	0	0	0	0
9	7384	1548	212	22	3	0	0	0	0	0	0	0	0	0	0
10	824	371	154	87	15	0	0	0	0	0	0	0	3861	18604	0
11	68	15	6	0	0	0	0	0	0	0	0	0	0	0	0
12	467	136	42	24	11	0	0	0	0	0	0	0	0	0	0
13	971	295	135	69	6	0	0	0	0	0	0	0	145	23231	0
14	1024	631	300	193	39	0	0	0	0	0	0	0	42	41164	17460
15	640	256	81	42	12	0	0	0	0	0	0	0	0	9591	1049
16	15202	3284	488	162	22	0	0	0	0	0	0	0	0	0	0
17	1449	267	47	27	6	0	0	0	0	0	0	0	0	0	0
18	9211	1163	211	105	20	0	0	0	0	0	0	0	0	0	0
19	6728	766	87	23	3	0	0	0	0	0	0	0	0	0	0
20	1404	421	160	121	53	0	0	3	21	0	528	1145	1576	47164	42052
21	1517	427	115	74	18	0	0	0	0	0	0	0	0	0	0
22	299	55	8	2	0	0	0	0	0	0	0	0	0	0	0
23	114	21	4	0	0	0	0	0	0	0	0	0	0	0	0
24	333	116	45	26	17	0	0	0	0	0	0	0	0	0	0
25	2481	1129	101	18	0	9	106	5	0	0	2552	22654	10163	25457	172
26	472	111	29	5	0	0	0	0	0	0	0	0	0	0	0
27	92	22	3	0	0	0	0	0	0	0	0	0	0	0	0
28	1843	531	199	65	12	0	0	0	0	0	0	0	0	0	0

29	496	164	55	29	6	0	0	0	0	0	2008	35806	34588	35190	45
30	4029	2601	1818	1619	684	0	0	0	0	0	0	0	0	0	0
31	3713	1917	971	277	48	37	0	0	0	0	16253	17018	12976	1780	0
32	1359	535	161	87	42	0	0	0	0	0	0	0	0	12	0
33	15130	3893	1171	694	401	0	0	0	0	0	0	0	0	0	0
34	1483	555	257	184	68	0	0	0	0	0	0	0	0	0	0
35	1780	662	231	95	17	0	0	0	0	0	0	0	0	0	0
36	4381	1145	312	150	30	0	0	0	0	0	0	0	0	0	0
37	2267	545	164	85	39	0	0	0	0	0	0	0	0	0	0
38	2058	417	103	27	1	0	0	0	0	0	0	0	0	0	0
39	655	142	28	15	1	0	0	0	0	0	0	0	0	0	0
40	2711	225	45	11	0	0	0	0	0	0	0	0	0	0	0
41	675	251	105	96	41	0	0	0	0	0	0	0	0	0	0
42	1157	145	78	65	18	0	0	0	0	0	0	0	0	0	0
43	1118	115	6	3	0	0	0	0	0	0	0	0	0	0	0
44	10726	901	226	78	4	0	0	0	0	0	0	0	0	0	0
45	127	12	4	12	2	0	0	0	0	0	0	0	0	0	0
46	6181	826	202	64	11	0	0	0	0	0	0	0	0	0	0
47	3269	148	10	1	0	0	0	0	0	0	0	0	0	0	0
48	9918	1772	607	246	80	0	0	0	0	0	0	0	0	0	0
49	114	43	20	9	0	0	0	0	0	0	0	0	0	0	0
50	791	125	19	8	2	0	0	0	0	0	0	0	0	0	0
51	958	195	64	30	5	0	0	0	0	0	0	0	0	0	0
52	457	165	63	25	2	0	0	0	0	0	0	0	0	0	0
53	1925	229	41	8	1	0	0	0	0	0	0	0	0	0	0
54	12663	552	228	92	11	0	0	0	0	0	0	0	0	0	0
55	3301	394	60	18	1	0	0	0	0	0	0	0	0	0	0
56	100	16	2	0	0	0	0	0	0	0	1	0	0	80	0
57	675	100	26	11	2	0	0	0	0	0	0	0	0	0	0
58	145	47	7	1	0	0	0	0	0	0	0	0	0	0	0
59	1132	305	105	48	4	0	0	0	0	0	0	0	0	0	0
60	381	143	65	48	21	0	0	0	0	0	0	0	0	0	0

61	320	139	55	39	20	0	0	0	0	0	0	0	0	0	0
62	901	233	75	38	9	0	0	0	0	0	0	0	0	0	0
63	8854	3373	1146	586	147	0	0	0	0	0	0	0	0	0	0
64	50989	40916	14719	5606	876	0	0	0	0	0	0	0	0	0	0
65	113204	66447	10695	3662	395	0	0	0	0	0	0	0	0	0	0
66	80205	25941	4378	850	104	0	0	0	0	0	0	0	0	0	0
67	33526	14514	5650	2697	460	0	0	0	0	0	0	0	0	0	0
68	71110	26384	352	0	0	0	0	0	0	0	0	0	0	0	0
69	60088	6659	23	1	0	0	0	0	0	0	0	0	0	0	0
70	24690	16449	7074	3021	1088	0	0	0	0	0	0	0	0	0	0
71	73716	12230	1177	438	42	0	0	0	0	0	0	0	0	0	0
72	10044	2353	1095	932	111	0	0	0	0	0	0	0	0	0	0
73	48969	15823	424	71	26	0	0	0	0	0	0	0	0	0	0
74	119414	94117	49853	37162	14101	0	0	0	0	0	0	0	0	0	0
75	712	141	35	23	12	0	0	0	0	0	0	0	0	0	0
76	148	31	5	1	0	0	0	0	0	0	0	0	0	0	0
77	37	36	25	25	4	0	0	0	0	0	0	0	0	0	0
78	804	284	149	127	143	0	0	0	0	0	0	0	0	0	0
79	3060	1778	777	490	163	0	0	0	0	0	0	0	0	0	0
80	619	276	143	103	86	0	0	0	0	0	0	0	0	0	0
81	967	311	118	86	90	0	0	0	0	0	0	0	0	0	0
82	1205	203	93	62	25	0	0	0	0	0	0	0	0	0	0
83	3211	71	23	18	9	0	0	0	0	0	0	0	0	0	0
84	2619	296	81	41	15	0	0	0	0	0	0	0	0	0	0
85	79532	17863	761	21	0	0	0	0	0	0	0	0	0	0	0
86	77162	12312	0	0	0	0	0	0	0	0	0	0	0	0	0
87	41516	31273	581	293	113	0	0	0	0	0	0	0	0	0	0
88	2852	732	192	73	4	0	0	0	0	0	0	0	0	0	0
89	568	74	22	6	0	0	0	0	0	0	0	0	0	0	0
90	6778	1143	393	180	41	0	0	0	0	0	0	0	0	0	0
91	4306	281	113	111	116	0	0	0	0	0	0	0	0	0	0
92	34955	21791	3676	346	8	0	0	0	0	0	0	0	0	0	0

93	79319	27705	2905	389	175	0	0	0	0	0	0	0	0	0	0
94	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
95	15020	33981	17651	2268	1494	0	0	0	0	0	0	0	0	0	0
96	189380	52447	1734	65	0	0	0	0	0	0	0	0	0	0	0
97	42247	51166	7968	0	0	0	0	0	0	0	0	0	0	0	0
98	20484	74035	7257	0	0	0	0	0	0	0	0	0	0	0	0
99	195986	60013	8176	0	0	0	0	0	0	0	0	0	0	0	0
100	22222	33927	902	0	0	0	0	0	0	0	0	0	0	0	0
101	29670	47037	14222	943	0	0	0	0	0	0	0	0	0	0	0
102	76649	26660	2149	10	0	0	0	0	0	0	0	0	0	0	0
103	26229	25	0	0	0	0	0	0	0	0	0	0	0	0	0
104	19062	52025	22956	2	0	0	0	0	0	0	0	0	0	0	0
105	27498	43878	53970	1348	0	0	0	0	0	0	0	0	0	0	0
106	11956	22579	33282	91	0	0	0	0	0	0	0	0	0	0	0
107	17770	24865	11658	0	0	0	0	0	0	0	0	0	0	0	0
108	20161	15218	27270	2178	0	0	0	0	0	0	0	0	0	0	0
109	56146	58906	10358	356	0	0	0	0	0	0	0	0	0	0	0
110	30161	23422	23473	4301	0	0	0	0	0	0	0	0	0	0	0
111	18178	13092	7426	0	0	0	0	0	0	0	0	0	0	0	0
112	38221	25687	12839	196	0	0	0	0	0	0	0	0	0	0	0
113	43860	20214	10	0	0	0	0	0	0	0	0	0	0	0	0
114	69283	25222	640	54	0	0	0	0	0	0	0	0	0	0	0
115	93198	10920	318	5	0	0	0	0	0	0	0	0	0	0	0
116	163912	51592	1489	1	0	0	0	0	0	0	0	0	0	0	0
117	177653	44168	70	0	0	0	0	0	0	0	0	0	0	0	0
118	61798	21674	377	0	0	0	0	0	0	0	0	0	0	0	0
119	42882	753	32	0	0	0	0	0	0	0	0	0	0	0	0
120	45110	86522	0	0	0	0	0	0	0	0	0	0	0	0	0
121	14535	66160	0	0	0	0	0	0	0	0	0	0	0	0	0
122	3030	38936	0	0	0	0	0	0	0	0	0	0	0	0	0
123	0	38682	0	0	0	0	0	0	0	0	0	0	0	0	0
124	37284	0	0	0	0	0	0	0	0	0	0	0	0	0	0

125	4202	36	0	0	0	0	0	0	0	0	90	3895	3498	4204	0
126	468	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127	1789	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	39921	4702	0	0	0	0	0	0	0	0	0	0	0	0	0
129	6876	2283	27	0	0	0	0	0	0	0	64	943	1262	218	0
131	5561	0	0	0	0	0	0	0	0	0	0	0	0	0	0
132	32061	108856	0	0	0	0	0	0	0	0	0	0	0	0	0
133	32590	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	32287	648	0	0	0	0	0	0	0	0	0	0	0	0	0
135	195033	37271	0	0	0	0	0	0	0	0	0	0	0	0	0
136	3918	153942	0	0	0	0	0	0	0	0	0	0	0	0	0
137	99482	2645	0	0	0	0	0	0	0	0	0	0	0	0	0
138	59380	7653	0	0	0	0	0	0	0	0	0	0	0	0	0
139	31060	16934	0	0	0	0	0	0	0	0	0	0	0	0	0
140	48677	9264	0	0	0	0	0	0	0	0	0	0	0	0	0
141	28884	12303	0	0	0	0	0	0	0	0	0	0	0	0	0
142	4434	0	0	0	0	0	0	0	0	0	0	0	0	0	0
143	62432	0	0	0	0	0	0	0	0	0	0	0	0	0	0
144	1741	0	0	0	0	0	0	0	0	0	0	0	0	0	0
148	110972	10579	1683	323	28	0	0	0	0	0	0	0	0	0	0
149	120517	217	12	0	0	0	0	0	0	0	0	0	0	0	0
150	43899	174849	0	0	0	0	0	0	0	0	0	0	0	0	0
152	16980	38800	0	0	0	0	0	0	0	0	0	0	0	0	0
153	313	102088	0	0	0	0	0	0	0	0	0	0	0	0	0
154	110370	18124	0	0	0	0	0	0	0	0	0	0	0	0	0
155	49292	3913	0	0	0	0	0	0	0	0	0	0	0	0	0
156	69036	3768	0	0	0	0	0	0	0	0	0	0	0	0	0
157	55947	61	6	0	0	0	0	0	0	0	0	0	0	0	0
158	34179	896	92	0	0	0	0	0	0	0	0	0	0	0	0
159	6080	36	2	0	0	0	0	0	0	0	0	0	0	0	0
160	1209	1218	120	0	0	0	0	0	0	0	0	0	0	0	0
163	1791	2949	2030	679	28	0	0	0	0	0	0	0	0	0	0

164	64158	595	270	403	0	0	0	0	0	0	0	0	0	0	0
165	100255	9005	328	20	0	0	0	0	0	0	0	0	0	0	0
166	573	6400	619	136	0	0	0	0	0	0	0	0	0	0	0
167	102519	775	10	0	0	0	0	0	0	0	0	0	0	0	0
168	25009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
172	1549	0	0	0	0	0	0	0	0	0	0	0	0	0	0
174	52715	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	4798	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	17643	63109	0	0	0	0	0	0	0	0	0	0	0	0	0
177	37014	249	0	0	0	0	0	0	0	0	0	0	0	0	0
178	64793	0	0	0	0	0	0	0	0	0	0	0	0	0	0
179	29339	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	43094	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	6407	0	0	0	0	0	0	0	0	0	0	0	0	0	0
182	17409	0	0	0	0	0	0	0	0	0	0	0	0	0	0
183	2091	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	832	94	11	0	0	0	14	508	0	0	0	0	0	0	0
192	0	0	0	0	0	12	54	24	0	0	0	0	0	0	0
193	444	0	0	0	0	0	0	0	0	0	0	0	0	0	0
194	22436	0	0	0	0	0	0	0	0	0	0	0	0	0	0
195	1807	0	0	0	0	0	0	0	0	0	0	0	0	0	0
197	1798	29	0	0	0	42	79	323	32	0	0	0	0	0	0
198	3276	7	0	0	0	0	227	25	0	0	0	0	0	0	0
199	32791	689	0	0	0	0	0	0	0	0	0	0	0	0	0
200	36303	375	0	0	0	0	0	0	0	0	0	0	0	0	0
201	11448	1122	0	0	0	0	0	0	0	0	0	0	0	0	0
202	49624	0	0	0	0	0	0	0	0	0	0	0	0	0	0
203	27006	161	0	0	0	0	0	0	0	0	0	0	0	0	0
204	4261	0	0	0	0	0	0	0	0	0	0	0	0	0	0
205	31870	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	12114	177	0	0	0	2	960	0	0	0	0	0	0	0	0
207	27766	34	0	0	0	0	0	0	0	0	0	0	0	0	0

208	24273	368	0	0	0	0	0	0	0	0	0	0	0	0	0
209	38135	19	0	0	0	0	0	0	0	0	0	1231	6825	63743	0
210	46391	10	0	0	0	0	0	0	0	0	0	0	1	0	0
211	17	0	0	0	0	1	45	619	104	0	0	0	0	0	0
212	1896	75	4	0	0	0	0	0	166	0	0	0	0	0	0
213	332	0	0	0	0	0	0	188	9	0	0	0	0	0	0
214	699	7	0	0	0	0	0	237	324	0	0	0	0	0	0
215	1035	0	0	0	0	0	0	0	0	0	0	104	876	13188	0
216	15	1	0	0	0	0	207	1227	0	0	0	972	2842	16173	0
217	1078	1	0	0	0	279	644	433	0	0	0	0	0	0	0
218	7009	2	0	0	0	97	135	788	2	0	0	0	0	0	0
219	27	0	0	0	0	0	632	133	0	0	0	0	0	0	0
220	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221	6188	0	0	0	0	0	0	0	0	0	0	0	0	0	0
222	6772	0	0	0	0	0	0	0	0	0	0	0	0	0	0
223	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
224	0	0	0	0	0	0	0	0	0	0	0	1497	2189	2146	0
225	301	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226	3508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
227	806	2	0	0	0	0	35	480	0	0	0	0	0	0	0
228	1172	0	0	0	0	0	0	0	0	0	0	0	0	0	0
234	238	0	0	0	0	0	237	5859	7421	0	0	0	2625	7545	0
241	171	25	4	1	0	0	0	0	0	0	0	0	109	35376	11
242	91	13	1	0	0	0	0	0	0	0	0	0	900	7147	0
243	181	83	24	8	0	0	0	0	0	0	0	0	499	1284	0
244	96	24	6	9	4	0	0	0	0	0	0	0	0	0	0
245	47	36	22	15	0	0	0	0	0	0	0	0	2876	15341	0
246	26	0	0	0	0	0	0	0	0	0	1	4	0	0	0
247	22	2	0	0	0	0	0	0	0	0	22	11	2498	11933	0
248	138	35	7	9	1	0	0	0	0	0	0	53	1925	366	0
249	469	114	29	21	11	0	0	0	0	0	0	0	0	0	0
250	1212	371	163	141	43	0	0	0	0	0	0	0	0	0	0

252	216	23	1	0	0	0	0	0	0	0	0	0	0	0	0
253	562	125	40	9	0	0	0	0	0	0	0	0	0	0	0
254	159	61	22	4	0	0	0	0	0	0	0	0	0	0	0
255	38	2	0	0	0	0	0	0	0	0	0	0	0	0	0
257	537	353	33	0	0	0	0	0	0	0	0	0	0	0	0
258	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
259	52	9	0	0	0	0	0	0	0	0	0	0	0	0	0
272	200	360	38	0	0	0	0	0	0	0	0	0	0	0	0
280	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
281	335	37	0	0	0	0	0	0	0	0	0	0	0	0	0
282	14	24	2	0	0	0	0	0	0	0	0	0	0	0	0
283	1	117	13	0	0	0	0	0	0	0	0	0	0	0	0
284	101	92	10	4	0	0	0	0	0	0	0	0	0	0	0
285	79	76	77	14	5	0	0	0	0	0	0	0	0	0	0
288	621	264	110	81	35	0	0	0	0	0	0	0	0	0	0
292	20	0	0	0	0	0	1601	7552	3155	0	0	0	0	0	0
293	0	0	0	0	0	36	780	5992	85	0	0	0	0	0	0
294	638	16	0	0	0	70	1773	5174	12189	0	0	0	0	0	0
295	143	87	9	0	0	0	0	0	0	0	0	0	0	0	0
298	1	0	0	0	0	0	732	29	188	0	0	0	0	0	0
300	167	98	68	77	34	0	0	0	0	0	0	0	0	0	0
301	82	32	10	12	0	0	0	0	0	0	0	0	0	0	0
302	55	15	4	0	0	0	0	0	0	0	0	0	0	0	0
305	0	0	0	0	0	0	530	0	0	0	0	0	0	0	0
307	139	0	0	0	0	0	344	571	2613	0	0	0	0	0	0
308	294	150	83	53	12	0	0	0	0	0	0	0	0	0	0
314	629	118	1	0	0	0	794	4841	5615	0	0	0	0	0	0
315	461	6	0	0	0	3	140	2872	742	0	0	0	0	0	0
316	943	19	0	0	0	0	0	0	0	0	0	0	0	0	0
317	0	0	0	0	0	0	145	0	0	0	0	0	0	0	0
318	74	0	0	0	0	0	294	146	0	0	0	0	0	0	0
319	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0

320	308	0	0	0	0	0	0	1329	0	0	0	0	0	0	0
321	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
322	1327	423	166	60	0	0	0	0	0	0	0	0	0	0	0
323	107	13	0	0	0	0	0	0	0	0	0	0	0	0	0
324	111	14	1	0	0	0	0	0	0	0	0	0	0	0	0
325	41	4	0	0	0	0	0	0	0	0	0	0	0	0	0
326	51	3	0	0	0	0	0	0	0	0	0	0	0	0	0
330	56	1	0	0	0	0	591	2162	2114	0	0	0	0	0	0
332	215	11	0	0	0	0	492	2646	1583	0	0	0	0	0	0
333	2721	327	0	0	0	0	0	443	0	0	0	0	0	0	0
334	1149	0	0	0	0	0	0	0	0	0	0	0	0	0	0
335	11796	187	16	0	0	0	0	0	0	0	0	0	0	0	0
336	5655	17	0	0	0	0	0	43	0	0	0	0	0	0	0
338	352	456	46	0	0	0	0	0	0	0	0	0	0	0	0
339	2962	300	262	26	0	0	0	0	0	0	0	0	0	0	0
340	143	155	16	0	0	0	0	0	0	0	0	0	0	0	0
341	610	48	14	1	0	0	40	205	0	0	0	0	0	0	0
342	1281	915	0	0	0	0	537	762	1069	0	0	0	0	0	0
343	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0
344	1	0	0	0	0	0	176	0	0	0	0	0	0	0	0
345	1	21	5	0	0	0	0	75	37	0	0	0	0	0	0
346	50	12	0	0	0	0	0	110	1	0	0	0	0	0	0
347	381	118	46	25	16	0	0	0	0	0	0	0	0	0	0
348	108	6	0	0	0	0	0	125	75	0	0	0	0	0	0
349	1050	351	114	19	0	0	0	282	6572	890	0	0	0	0	0
350	355	162	100	77	27	0	0	0	0	0	0	0	0	0	0
351	999	382	184	147	42	0	0	0	0	0	0	0	0	0	0
352	1233	520	245	166	56	0	0	0	0	0	0	0	0	0	0
353	1138	502	225	146	31	0	0	0	0	0	0	0	0	0	0
354	303	80	30	23	2	0	19	1	0	0	0	0	0	0	0
355	4680	1587	825	702	452	0	0	0	0	0	0	0	0	0	0
356	408	52	6	3	1	0	33	29	112	0	0	0	0	0	0

Total	Class 3	Class 4	Class 5	Class 6	Class 7	Class 3	Class 4	Class 5	Class 6	Class 7	Class 3	Class 4	Class 5	Class 6	Class 7
	5144954	2349214	392397	78517	22653	596	12587	46241	44229	890	22434	86993	110961	431953	60788

Notes:
1) Regions without wind resource are not listed. Regions 357 and 358 are Canada and Mexico. WinDS does not include wind resources in those countries.
2) Shallow offshore refers to land 5-50 nm to shore with water < 30m deep
3) Deep offshore refers to land 5-50 nm to shore with water > 30m deep